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14. ABSTRACT

The UPSIDE Project addressed the threat against ships in ports and critical harbor infrastructure. A disciplined system engineering process was used to achieve three principle objectives. The objectives were to 1) Develop an integrated interoperable test-bed supported by a plug and play infrastructure, 2) Develop a robust modeling and simulation (M&S) capability and 3) Develop an undersea perimeter defense system that can either be operated in a standalone mode or integrated into a comprehensive maritime defense system. The development process itself involved design, build, and test that went through a number of spirals. The UPSIDE team successfully addressed all three of the project's objectives.

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Rhode Island
Economic Development Corporation

Undersea Perimeter Security Integrated Defense Environment (UPSIDE)

Final Report

November 29, 2011

Supporting Materials

This Report summarizes Project UPSIDE and the results achieved which are fully documented in the following documents – all can be made available upon request to John Riendeau, 315 Iron Horse Way, Providence, Rhode Island 02903. Tel. 401-27809100 or jriendeau@riedc.com

UPSIDE Phase I Quonset Point In-Water Test Report, 30 June 2008

UPSIDE Phase II Naval Station Newport, Pier 1 In-Water Test Final Report, 28 July 2009

UPSIDE Phase III Best of Breed Report, 31 December 2009

UPSIDE Phase III First Demonstration Report (USCG Exercise Vigilant Hope), 10 June 2010

UPSIDE Phase III Providence Emergency Management Agency Port Security Demonstration #2 Test Report, 31 July 2011

Table of Contents

Figures & Tables

1 Final Report - Project UPSIDE Objectives

Project UPSIDE commenced with a Phase I kickoff meeting in July 2007 and continued through two additional phases, concluding in July 2011 with the issuing of this final report. This Office of Naval Research (ONR) project was a significant initiative coordinated and managed by the Rhode Island Economic Development Corporation (RIEDC) to address the underwater threat against ships in ports and critical harbor infrastructure, an area that had received considerably less priority and attention by the homeland security and defense communities. Project UPSIDE was funded through a series of congressional appropriations under RDT&E, Navy PE 0602123N; FORCE PROTECTION.

A disciplined system engineering process was used throughout the life of the program. Requirements Definition Documentations (RDD) resulted from the application of IEEE P1220 checklist categories and the use of Design Reference Missions (DRM) to assist in and validate the design approach. Use case analyses were conducted that allowed tailoring of system interfaces to the needs of the user. An open system architecture was defined and interface specifications were developed to provide easy interface to external sensors and assets to the UPSIDE command and control core. The development process employed functional, interface and operational metrics to support overall system development and evaluation. The development process itself involved design, build and test process that went through a number of spirals.

The Project UPSIDE initiative was structured to satisfy three ***principal objectives*** that are described along with accomplishments in sections 1.1, 1.2, and 1.3. Section 2.0 summarizes the demonstrations conducted during each of the three phases. Section 3.0 summarizes the lessons learned from the spiral development process and Section 4.0 addresses transition initiatives and opportunities. Section 5.0 presents conclusions. Key participants involved over the course of Project UPSIDE are shown in Figure 1.

Figure 1. Key Project UPSIDE Participants

1.1 Objective 1: An Integrated Interoperable Test-Bed

Provide an integrated, interoperable test-bed environment supported by a plug and play infrastructure that allows prototype undersea security systems to be evaluated in an end – to – end security system context using realistic operational scenarios and that is complimentary with other on-going initiatives in port and harbor security initiatives.

A number of key features were identified to best achieve the integrated, interoperable test bed objective. These features included:

- Use of open, commercial system architecture using a commercial enterprise service bus and open standards and protocols
- Defined external interfaces enabling a "plug and play" capability for various sensors or reactive assets that are being developed by various companies
- A command and control core that provides processing and display for data fusion, course of action aids, and situational awareness
- Use of standard approved data bases that can be easily updated or changed as additional information becomes available to improve realism
- Incorporation of a first responder component that provides an interoperable data communications system to responders and enables the tracking and sharing of real time information over a wide area network
- A data capture and replay feature and provides timely reconstruction and assessment of test bed events

If an interoperable test-bed is to be achieved, choosing an open architecture infrastructure is a critical aspect that enables flexible, rapid and efficient interfacing to a myriad of technologies selected for evaluation. At the initiation of Project UPSIDE and in recognition of Objective 1, Rite-Solutions initiated the design of the Command and Control System (CCS) architecture infrastructure as a Service Oriented Architecture (SOA). A commercial Enterprise Service Bus (ESB) from BEA Aqualogic was chosen initially since a zero cost but somewhat limited developer license was available. The infrastructure has since been migrated to a JBOSS open source ESB. Over the three UPSIDE phases, services were gradually developed and refined to provide new and increasing levels of functionality.

Adapter services designed to ingest sensor information from a mix of HF Active Sonar systems, Cameras, and AUV's have been developed over the UPSIDE phases. The adapter services provide the mediation necessary for ESB communication with unique sensor and vehicle devices, and in turn these devices communicate with the CCS. The exact requirements of each adapter service are dependent on the level of control and kinds of data associated with the external device or system. The ability to rapidly and cost effectively interface the UPSIDE system to new sensors is a key attribute of the UPSIDE CCS and a measure of effectiveness for any test bed given the need for comparison of alternate and potentially competing technologies. With this capability, quantitative measures of performance in actual environments are within the grasp of the end user.

The resulting open system architecture is shown in Figure 2 . Representative operational display content from the UPSIDE Command and Control system is shown in Figure 3.

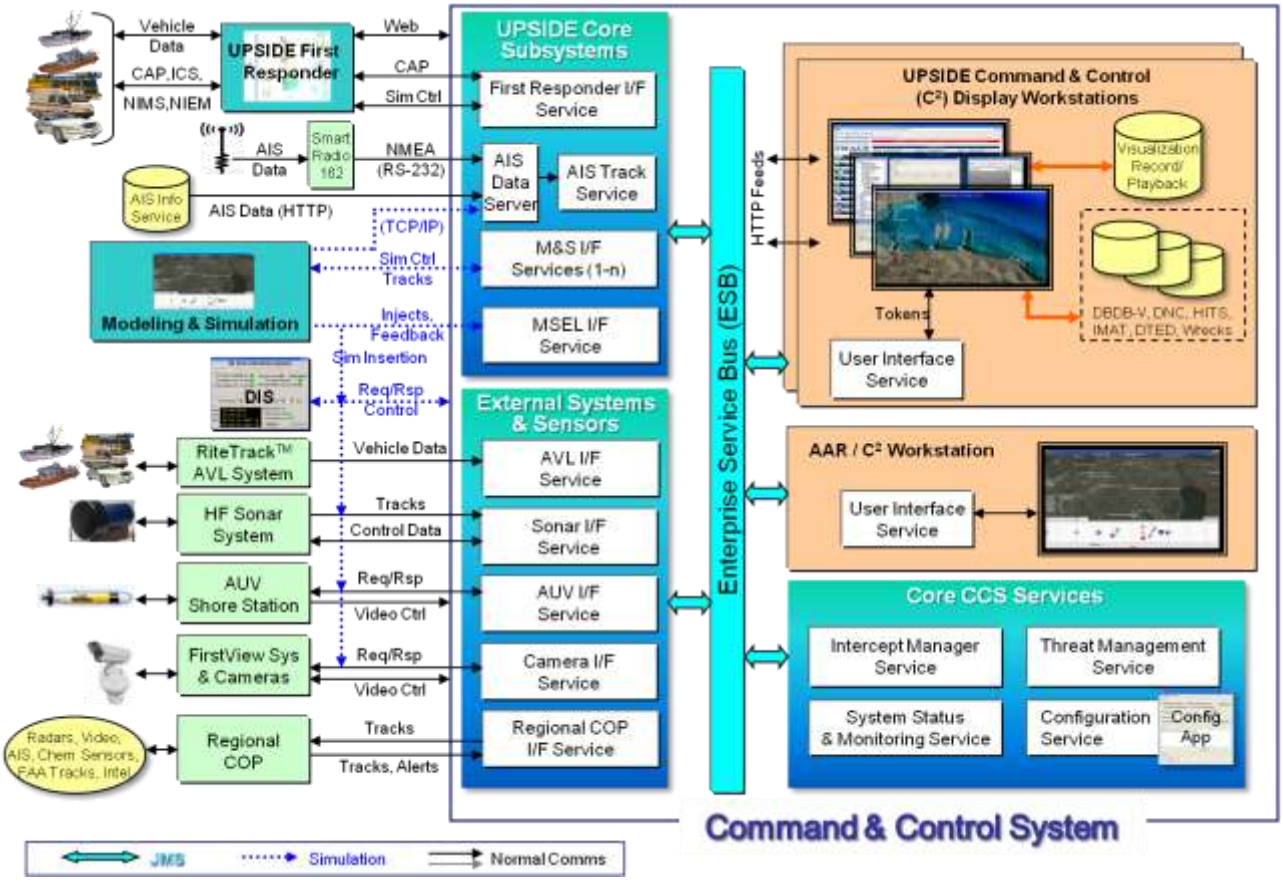

Figure 2. UPSIDE Open System Architecture

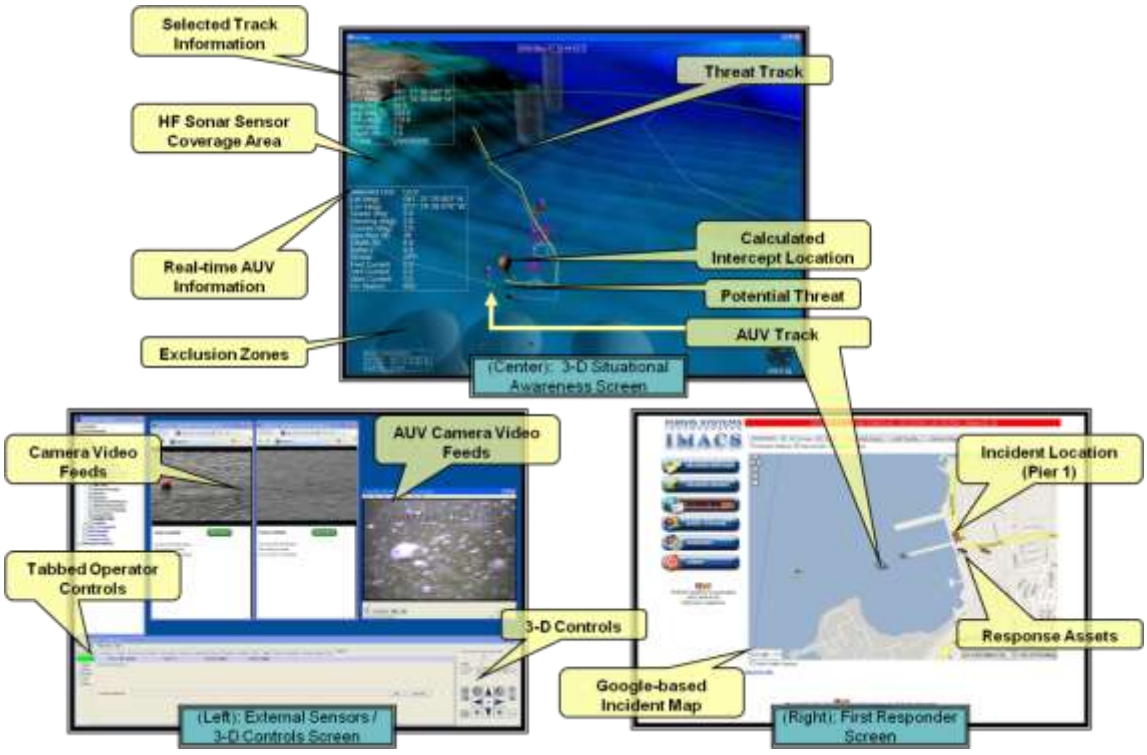

Figure 3. UPSIDE Command & Control Operational Displays

Examples of efficient test-bed operation were drawn from the final UPSIDE demonstration conducted with the Providence EMA (PEMA) during October 2010. Rapid and therefore cost effective integration with Raytheon's Athena system involved only several weeks of effort and was greatly facilitated by use of commercial open architectures and standards. In addition, a new HF active sonar system from SoneSys was interfaced to the Command and Control System (CCS) for the PEMA demonstration. The last minute nature of the decision to include SoneSys forced a rapid but disciplined development spiral to take place. The Sonar-to-CCS interface also required only several weeks of effort to build the protocol translator and was completely successful.

Another capability important to this test bed objective also overlaps the M&S capability further discussed in paragraph 1.2. UPSIDE developed the ability to simulate sensors and vehicles at the interface level, which means that a test bed evaluation can be conducted with a mix of real and virtual assets. This feature, coupled with the use of standard approved data bases that can be easily changed or updated as new information becomes available, enables more robust testing in a realistic end-to-end context at reduced cost by avoiding the time expense, and potential delays associated with total reliance on all real assets.

Through the demonstrations conducted in all three phases, the Project UPSIDE team has been fully successful in meeting Objective #1. The UPSIDE capability can be readily leveraged against any test-bed requirement.

1.2 Objective 2: A Robust Modeling and Simulation (M&S) Capability

Using relevant scenarios and realistic operational conditions, provide a simulation environment that supports robust system performance and interoperability evaluation as well as mission rehearsal, mission execution and post mission assessment for personnel training and evaluation of the completeness and quality of plans and procedures

A basic M&S capability was initiated in Phase I with a basic UPSIDE system requirement to (1) provide a rich, 3D visualization of geographic locations (including land-water interfaces) using overlays from GIS-referenced data bases; (2) model sensor systems and manned/unmanned vehicles; (3) utilize environmental data such as bathymetry and historical sound speed profiles; (4) define dynamic (i.e., over time) scenarios including a master scenario events list (MSEL), the aforementioned requirements plus threat models and behaviors, and (5) run dynamic simulations. The scenario builder allows various scenarios to be constructed for end-to-end system evaluation, mission rehearsal or training applications. The scenarios controller allows for either scripted play or real time adjustments during the course of the scenario. The M&S capability was used to various degrees over all three UPSIDE phases. The modeling and simulation architecture that was developed for the UPSIDE system is shown in Figure 4.

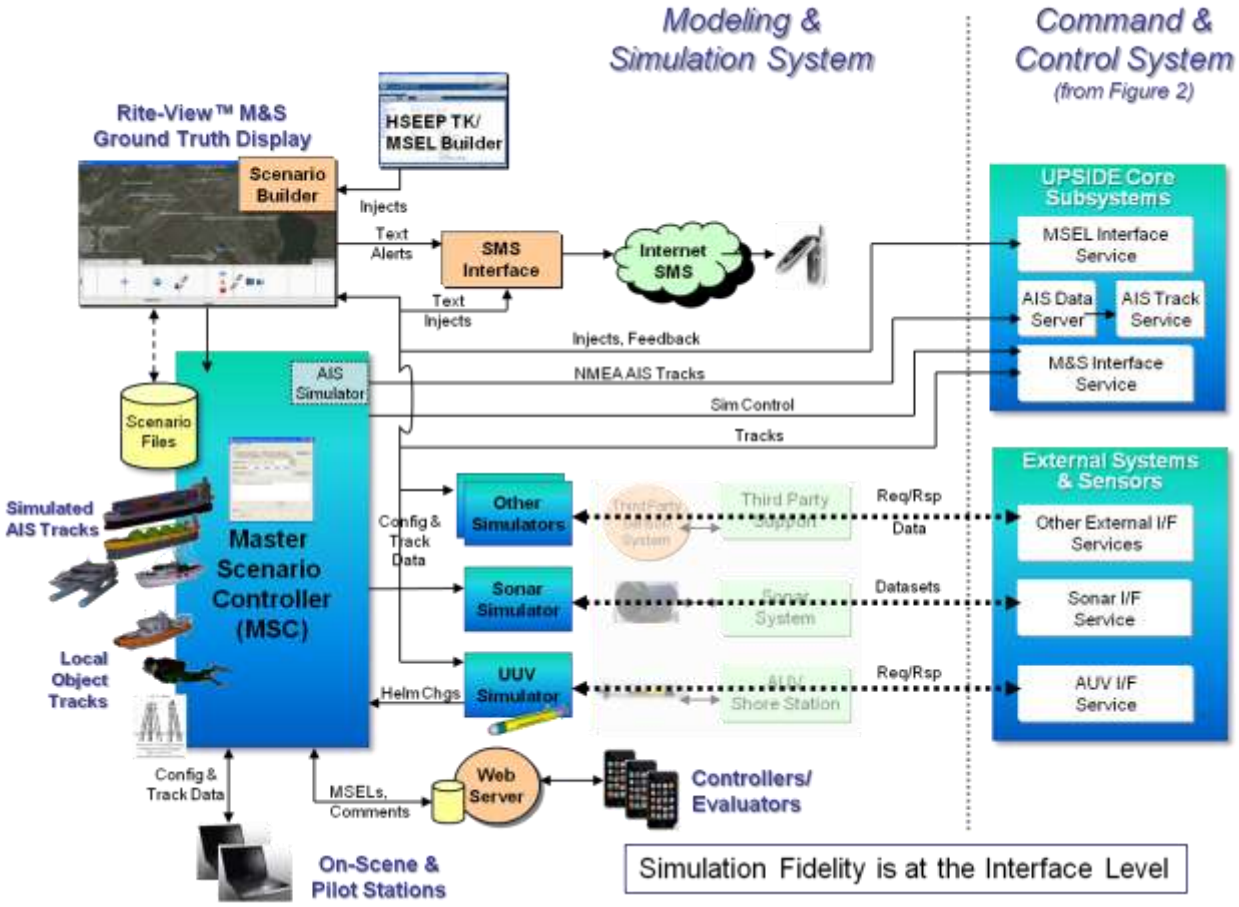

Figure 4. UPSIDE M&S Architecture

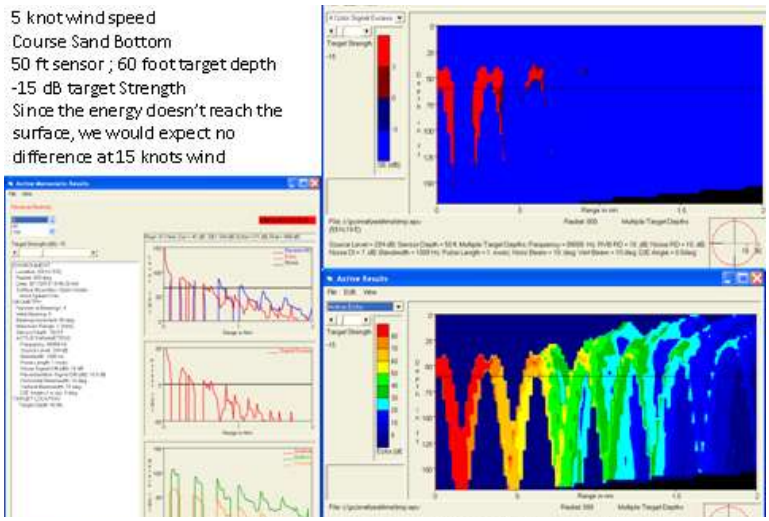

Figure 5. Sample sonar performance analysis output

M&S became much more of a focus area during UPSIDE Phase III with the Navy customer desire to have a capability to (1) compare various system or technology alternatives prior to in-water testing and (2) determine the number of assets required prior to deployment and their best employment when on scene. The report *""Best of Breed", a Comparative Evaluation through Modeling and Simulation (M&S)*" was delivered to the customer on 12/31/2009 in support of the first objective. An M&S methodology was described that provides the user with M&S toolsets for evaluation of point technologies over a range of simulated environments and threats by constructing and running scenarios that reflect relevant missions or mission segments and examining performance as a function of time. Operational performance is an excellent measure of Return on Investment (ROI) for the acquisition program manager. Therefore, "best of breed" for a set of point technologies such as high frequency active SONAR systems, RADAR systems and Electro-Optical/Infrared systems was the context for comparative evaluation within realistic operational environments and against a simulated spectrum of threats. Simulation fidelity was discussed as a critical element in the successful ranking of systems. Figure 5 is a sample sonar performance analysis output taken from the Best of Breed document. The predicted performance for this particular HF Sonar system in this environment clearly shows gaps in range coverage.

Further impetus to continue M&S development came from NAVSEA PMS480, the Anti-Terrorism/Force Protection Afloat Program Manager, via NUWC laboratory representatives in Newport, RI. PMS480 manages the Integrated Swimmer Defense (ISD) program and missing from the current ISD was the ability to perform acoustic and non-acoustic environmental modeling in advance of deployment. Such a capability, a system deployment aid (SDA), would greatly assist Navy personnel with their task of identifying the right numbers and types of sensors to deploy to a forward site and to optimally position those sensors to protect high value assets upon deployment. Project UPSIDE developed a user-friendly SDA M&S framework designed for use by Fleet personnel. A demonstration of the SDA was provided to NUWC and fleet participants in October 2010 and delivered to PMS 480 (See section 2)

Budget limitations prevented UPSIDE from completing the product for transition to the fleet.

Figure 6. UPSIDE Vigilant Hope Setup (Large Screens)

Another important aspect of the UPSIDE M&S capability is the ability to perform team training through simulated exercises. In May of 2010, UPSIDE personnel participated in a joint USCG and State of RI exercise named "Vigilant Hope", providing an UPSIDE system at a National Guard facility in Cranston, RI. See Figure 6. In addition to demonstrating improved situational awareness for the participants, an after action review (AAR) capability that had been developed was also demonstrated. With the playback capability designed for and built into the UPSIDE system, training scenarios could be replayed with overlays of exercise evaluator comments at critical times, such as key decision points. UPSIDE AAR capability demonstrated that post exercise analysis could be effectively addressed at the end of the exercise as opposed to what typically requires months of effort. In addition to the resulting cost/time savings, the UPSIDE AAR capability was proven more effective in providing participants lessons learned since the exercise events were still fresh in everyone's mind. The AAR feature is illustrated in Figure 7.

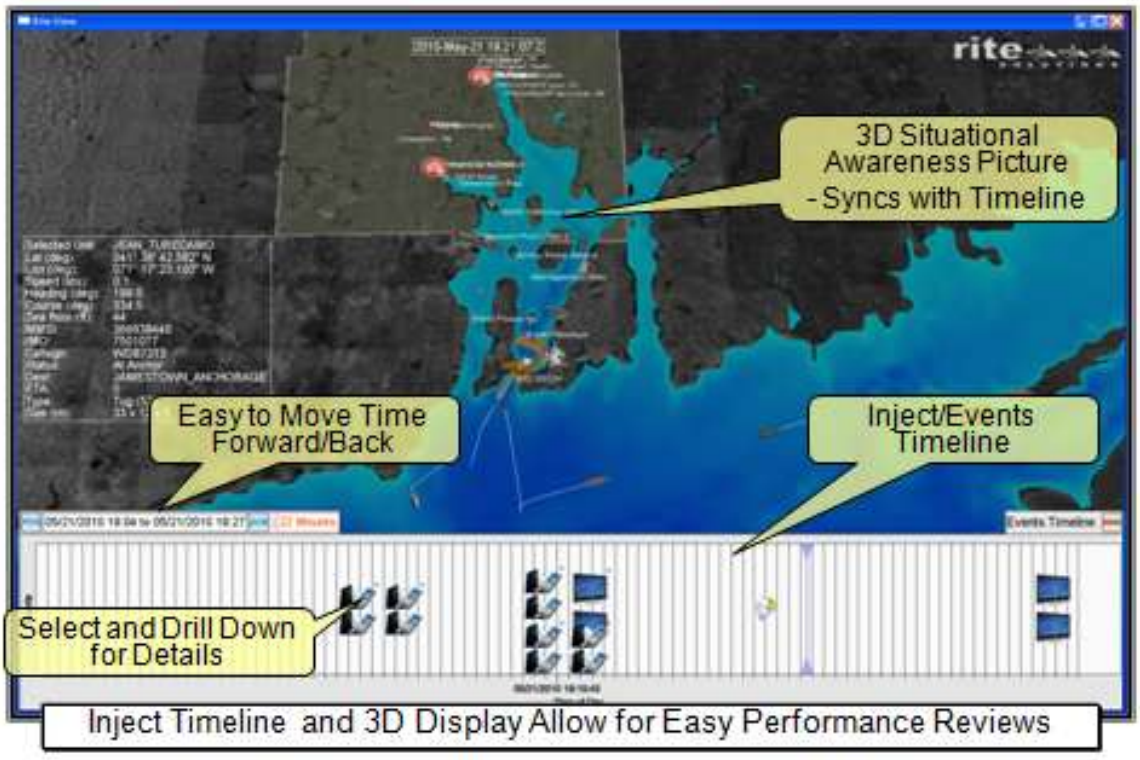

Figure 7. After Action Review Capability

1.3 Objective 3: An Undersea Perimeter Defense System

Provide an undersea perimeter defense system that can either be operated in a standalone mode or integrated into a comprehensive maritime defense system.

Figure 8. A Tiered Maritime Defense System

The ability to meet this objective was addressed through the in-water demonstrations conducted during every phase of Project UPSIDE. The vision for UPSIDE as an undersea perimeter defensive system included several configurations (Figure 8):

(1) Standalone operation protecting high value assets in a single area or few areas;

(2) As part of an integrated web of systems protecting distributed high value assets across multiple areas, and feeding a regional node system. The latter is referred to as a tiered maritime defense system concept.

For Phases I and II, the operation of the system was in a standalone mode. The in-water test performed for UPSIDE II was the most comprehensive of any accomplished by UPSIDE, involving multiple sensors and an unmanned undersea vehicle (UUV) controlled by the CCS. Refer to Section 2 for additional information. In Phase III, UPSIDE was integrated with Raytheon's Project Athena (i.e., Regional COP) in accordance with the Figure 8 'tiered' maritime defense system concept but with only a single protected harbor. The key players and exercise interfaces for the final UPSIDE demonstration is shown in Section 2

Consistent across all in-water testing was a mandate from ONR not to use human subjects, forcing the diver to be simulated. However, the fidelity of simulated threat divers became progressively more sophisticated for each succeeding demonstration, from a bubble air stream in Phase I, to calibrated, towed corner reflectors in Phase II and finally a towed physical diver model in Phase III.

The "core" UPSIDE perimeter defense system consists of the Rite-Solutions Command and Control System (CCS) and the PURVIS UPSIDE First Responder System (UFRS). Third party sensor/vehicle information and control are ingested and/or managed by the CCS through the adapter services described in paragraph 1.1 . Given that best of breed capabilities are within the context of specific customer requirements and environments, "the best" will be constantly changing over time as technologies mature and as customers' requirements change. It is therefore essential that any deployed core perimeter defense system be flexible and open as is UPSIDE.

2 Conclusions

The UPSIDE Team successfully addressed all three of the project's objectives that were identified at the start of the project. That success was the result of a disciplined system engineering process that was used throughout the life of the program that involved a spiral development process, updating requirements and capturing implementation documentation with each Phase while tracking lessons learned. The "core" UPSIDE perimeter defense system consists of the Rite-Solutions Command and Control System (CCS) and the PURVIS UPSIDE First Responder System (UFRS).

Objective 1. An Integrated Interoperable Test Bed

The core of the UPSIDE system key features that were designed into UPSIDE and successfully demonstrated included:

- Use of open, commercial system architecture using a commercial enterprise service bus and open standards and protocols
- Defined external interfaces enabling a "plug and play" capability for various sensors or reactive assets that are being developed by various companies
- A command and control core that provides processing and display for data fusion, course of action aids, and situational awareness
- Use of standard approved data bases that can be easily updated or changed as additional information becomes available to improve realism
- Incorporation of a first responder component that provides an interoperable data communications system to responders and enables the tracking and sharing of real time information over a wide area network
- A data capture and replay feature that provides timely reconstruction and assessment of test bed events

Objective 2. A Robust Modeling and Simulation (M&S) Capability

Key features designed in the UPSIDE M&S capability and successfully demonstrated included:

- A scenario builder that allows various scenarios to be constructed for end-to-end system evaluation, mission rehearsal or training applications
- A scenario controller that allows for either scripted play or real time adjustments during the course of the scenario
- Accepted environmental data models and standard data bases that accurately depict geographical and environmental information
- Models of sensor, reactive assets and threats models and behaviors that enable a varying mix of real and virtual assets to be utilized for testing, mission rehearsal and training applications
- A sensor modeling capability to allows various system technologies to be evaluated over a range of operational and environmental conditions prior to selection for in-water testing
- A System Deployment Aid that supports determination of the number of assets required for a given operation and once on station the optimum location of those assets
- An After Action Report (AAR) feature that enables post exercise analysis to be effectively addressed at the end of the exercise vice much later, providing not only cost/time savings but more effective lessons learned to exercise participants since the exercise events are still fresh in everyone's mind

Objective 3. An Undersea Perimeter Defense System operated in a standalone mode or integrated into a comprehensive maritime defense system.

The ability of UPSIDE to meet both of these operational modes was clearly demonstrated.

- The Phase II demonstration was a standalone mode that demonstrated to an audience of VIP's, how an AUV could be successfully vectored to within inches of its objective through a series of Sonar tracks, a radio link to the AUV, and a sophisticated AUV navigation system.
- During Phase III, a range of demonstrations were conducted that combined both real and virtual assets and linked to another larger range scale maritime defensive system as well as a variety of first responders.
- The advantages of the UPSIDE system over current capabilities in emergency operations centers were clearly demonstrated by providing features not typically available such as computer based situational awareness displays and After Action Report (AAR) capability.

Project UPSIDE, with its core Command and Control and First Responder components, enabled by its plug and play architecture and modeling and simulation capability represents a technically mature system that provides a cost effective environment for test and evaluation, mission planning, rehearsal and training, and a scalable maritime defense system.

Acronyms

#

3-D	Three Dimensional

-A-

AAR	After Action Review
AIS	Automatic Identification System
ASAP	Advanced Situational Awareness and Planning
AUV	Autonomous Underwater Vehicle
AVL	Automatic Vehicle Location

-B-

BAA	Broadband Agency Announcement

-C-

C^2	Command and Control
C4ISR	Command, Control, Communications, Computer and Intelligence, Surveillance, and Reconnaissance
CCS	Command and Control System
CGF	Computer Generated Forces
CONOPS	Concept of Operations
COP	Common Operating (or Operational) Picture
CPU	Central Processing Unit

-D-

DEM	Department of Environmental Management
DHS	Department of Homeland Security
DoD	Department of Defense
DRM	Design Reference Missions

-E-

EM	Emergency Management

EMA	Emergency Management Agency
ENS	Emergency Notification System
EOC	Emergency Operations Center
ERB	Environmental Review Board
ESB	Enterprise Service Bus

-F-

FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FD	Fire Department
FRS	First Responder System

-G-

GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface

-H-

HF	High Frequency
HVA	High Value Asset

-I-

ICS	Incident Command System
IMACS	Incident Management and Control System
IPT	Integrated Product Team
IR	Infra-Red
IRB	Institutional Review Board
ISD	Integrated Swimmer Defense

-J-

JOC	Joint Operations Center

-K-

kHz	Kilohertz (Hertz x 10^3)
Kt	Knot

-L-

LBL	Long BaseLine transponder navigation system
LE	Law Enforcement

-M-

M&S	Modeling and Simulation
MSC	Master Scenario Controller
MSEL	Master Scenario Events List

-N-

NGB	National Guard Bureau
NLDD	Non-Lethal Diver Deterrent
NSN	Naval Station Newport
NUWC	Naval Undersea Warfare Center

-O-

ONR	Office of Naval Research
OSA	Open Systems Architecture

-P-

PEMA	Providence Emergency Management Agency
PEO	Program Executive Office
PFD	Providence Fire Department
PMS	Program Management
PROVPORT	Port of Providence

-Q-

-R-

RADAR	Radio Detection And Ranging
RDC	Research & Development Center
RDD	Requirements Definition Document
RF	Radio Frequency
RHIB	Rigid Hull Inflatable Boat
RI	Rhode Island
RICOP	Rhode Island Common Operating Picture
RIDEM	Rhode Island Department of Environmental Management
RIEDC	Rhode Island Economic Corporation
RIEMA	Rhode Island Emergency Management Agency
RIGIS	Rhode Island Geographic Information Systems
ROI	Regional Modeling and Simulation Training Center
RiMSiM	Return on Investment

-S-

SA	Situational Awareness
SAF	Semi-Automated Forces
SDLW	Smiths Detection - LiveWave
SDA	System Deployment Aid
SOA	Services Oriented Architecture
SONAR	Sound Navigation And Ranging
STRI	Simulation, Training, and Range Instrumentation

-T-

TSA	Transportation Security Administration
TTA	Technology Transition Agreement

-U-

UFR	UPSIDE First Responder
UFRS	UPSIDE First Responder System
UI	User Interface

UPSIDE	Undersea Perimeter Security Integrated Defense Environment
USCG	United States Coast Guard
USV	Underwater Submersible Vehicle Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle

-V-

VIP	Very Important Person

-W-

-X-